11.0 ESTIMATING AND FORECASTING

11.1 METHODOLOGY

Cost-benefit analysis considers a range of costs and benefits in monetary terms. The benefits in this study include the prevention of potential airplane accidents and possible resulting injuries and fatalities from postcrash fires. This analysis accounts for the annual costs and benefits over a 16-year period from the first quarter of 2005 to the fourth quarter of 2020 (rule released first quarter 2005, designs completed first quarter 2008, fully implemented first quarter 2015, and end of study fourth quarter 2020). The analysis applies an inflation factor to the monetary values of both cost and benefit cash flows and discounts these cash flows to the year 2005. This allows the continuous stream of costs and benefits to be compared directly.

This analysis evaluated 13 different combinations of inerting, airplanes, and fuel tanks, as well as both a worldwide and a U.S.-only implementation (see fig. 11-1). The analysis was also divided into in-service, and new and future production airplanes. Freighter and passenger airplanes were evaluated separately.

Number	Inerting scenario	Fuel tanks	Airplanes	Systems
1	Onboard ground inerting	HCWT only	Large, medium, and small transports	PSA/membrane systems
2	Onboard ground inerting	All fuselage tanks	Large, medium, and small transports	PSA/membrane systems
3	Hybrid onboard ground inerting	HCWT only	Large, medium, and small transports	PSA/membrane systems
4	Hybrid onboard ground inerting	All fuselage tanks	Large, medium, and small transports	PSA/membrane systems
5	OBIGGS	All tanks	Large and medium transports	Membrane systems
			Small transports	PSA/membrane systems
6	Hybrid OBIGGS	HCWT only	Large and medium transports	Membrane systems
			Small transports	PSA/membrane systems
7	Hybrid OBIGGS	All tanks	Large and medium transports	Membrane systems
			Small transports	PSA/membrane systems
8	Ground-based inerting	HCWT only	All transports	—
9	Ground-based inerting	All fuselage tanks	All transports	—
10	OBIGGS	All tanks	Large and medium transports	Cryogenics systems
			Small transports	PSA/membrane systems
11	Hybrid OBIGGS	HCWT only	Large and medium transports	Cryogenics systems
			Small transports	PSA/membrane systems
12	Hybrid OBIGGS	All tanks	Large and medium transports	Cryogenics systems
			Small transports	PSA/membrane systems
13	Onboard liquid nitrogen inerting	—	—	—

Figure 11-1. Inerting Combinations Evaluated

<u>*Methodology Used to Quantify the Benefits*</u>

The following assumptions define the methodology used to estimate the benefits of an inerting system:

- The worldwide fuel tank explosion rate, as modified by the implementation of SFAR, provides an accurate model for future fuel tank explosion rates.
- Based on the DOT's latest estimate, the amount that society would pay to prevent a potential fatality is $2.7 million.
- The average value of a destroyed airplane would be approximately $20 million (Note: this is an average value that includes both new and older airplanes of different sizes that are susceptible to fuel tank explosions).

- Based on the Lockerbie, Scotland, investigation updated to 1997 dollars, the FAA estimates that investigation of an in-flight airplane explosion would cost the U.S. Government $30 million. Although the cost of the TWA Flight 800 accident investigation will be considerably greater than $30 million, that accident investigation cost was compounded by its location in the Atlantic Ocean. The number of fatalities for an in-flight accident is determined by the weighted average number of seats within each category multiplied by the weighted average load factor.
- The monetary value of the accidents is distributed annually and treated the same as the costs (i.e., escalated with inflation and discounted to year 2005).
- The estimated accident rate is based on the worldwide rate. The estimated number of accidents in the United States is based on the worldwide rate divided by U.S. operating hours.
- Each system's flammability exposure is used to calculate the expected benefits.
- Benefits for the U.S. fleet assume that N-registered airplanes are modified by the end of the implementation period (first quarter 2015). Benefits for the worldwide fleet assume that all airplanes have been modified by the end of the implementation period.

11.2 ECONOMIC MODEL FACTORS

Data Sources

This analysis used data constructed from several different sources, because no single database contained all the necessary data. Nevertheless, we believe that this data provides a sufficiently accurate base from which to complete a valid analysis. To the extent possible, this analysis used data from the 1998 ARAC fuel tank study.

The analysis based costs on 2000 US$ and calculated costs for in-service, production, and future airplane designs separately. This study does not include costs for supplemental type certificate fuel tanks, regulatory flexibility analysis, or international trade impact assessments.

Airplane costs are divided into recurring and nonrecurring, and then into the first of a model and each of its follow-on derivative models. The derivative model costs are generally lower than those for the first of a model. Nonrecurring costs include

- OEM engineering hours, including modifications and additions to fuel system components, interfaces, instruments and displays, relocation of other equipment, wiring, tubing and ducting, and avionics software and modules.
- Documents, including specifications and internal control documents.
- Manuals, including Airplane Flight Manual, Operations Manual, and Maintenance Manual.
- Production change records.
- Lab, ground, and flight tests.
- FAA or JAA certification.

Airplane costs for parts and installation include

- Major supplier parts.
- Major assemblies.
- Tubing, wiring, and ducting.
- SB and kitting costs for retrofitting.
- Special tooling.
- Labor for planning, installation, and inspection of production airplanes.
- Airline engineering.
- Airline technical publications.

- Material control.
- Initial maintenance training.
- Flight operations engineering.
- Installation labor.
- Airplane downtime.
- Consumables.

Annual airplane recurring costs include

- Maintenance checks and inspections.
- Unscheduled maintenance.
- Delay.
- Weight.
- Maintenance, ground service, and flight crew training.

Airport costs for ullage washing—both hydrant and cart systems—were divided into large, medium, and small airport costs. The nonrecurring costs include

- Engineering design.
- System installation labor, including relocation of other equipment.
- System parts and materials.
- Other equipment, including ground service equipment, electrical, and tooling.
- Emissions controls.

Recurring annual costs for the hydrant and cart systems include

- Nitrogen for washing.
- Washing labor.
- Washing power costs.
- Washing system maintenance, inspection, and training.

This study assumes that there is no systemic increase in airplane gate turn time. Appendix G lists added costs of a systemic delay caused by an inerting system. Turnaround times for the six airplane models are

- Large: 60 min
- Medium: 45 min
- Small: 20 min
- Regional turbofan: 15 min
- Regional turboprop: 15 min
- Business jet: 60 min

The cost analysis assumes that there are no cancellations, ATBs, or diversions for any of the systems.

This study assumes

- Fuel costs of $1 per gallon (see *Air Transport World*, January 2001).
- Cost for professionals of $110 per labor-hour (FAA estimate).
- Cost for technicians and mechanics of $75 per labor-hour (FAA estimate).
- Cost for ground service personnel of $25 per labor-hour (FAA estimate).

The cost-benefit analysis assumed the ramp-up time for introducing a fuel tank inerting system into existing and current in-production fleets to be 7 years from design certification. The analysis assumed no constraints on engineering, manufacturing, parts, or facilities.

The analysis used the Campbell-Hill forecast of unconstrained growth to estimate annual changes in airplane model types, after adjusting the Campbell-Hill data for ARAC airplane categories. This weighted average growth rate is estimated at 3.6%.

For cost estimates of applying an onboard system to new airplane designs, this study assumed the designs could be optimized in the initial design phase to minimize initial and recurring costs.

Number of airports: worldwide total, 1,200 (85 large, 101 medium, 1,014 small)

Number of U.S. airports modified for U.S.-operated airplanes:

- B category: 31
- C category: 37
- D category: 354

Number of foreign airports modified for U.S.-operated airplanes:

- All categories: 158

The Airport Facility Task Team provided recurring and nonrecurring airport costs (except for inerting labor). Inerting labor estimates were based on 20 min for small airplanes, 25 min for medium airplanes, and 30 min for large airplanes at $25 per hour for burdened ground service labor.

Airplane out-of-service costs are equivalent to the average lease rates for each airplane category.

Nonrecurring development and certification costs were based on the number of major and derivative airplane models within each category (large: 6 major, 16 derivative; medium: 3 major, 9 derivative; and small: 11 major, 42 derivative).

Airline per-fleet costs were based on an average of major and minor fleet costs.

The cost penalty per pound of added weight for each airplane category is based on 1998 ARAC cost estimates.

The worldwide and U.S. average nitrogen cost in US$ is $0.13 per 100 ft^3.

11.3 STUDY PERIOD

The costs and benefits are accounted for annually over a 16-year period from the first quarter of 2005 to the fourth quarter of 2020 (rule released first quarter 2005, designs completed first quarter 2008, fully implemented first quarter 2015, and end of study fourth quarter 2020).

11.4 IMPLEMENTATION

We assumed that any proposed new rules would affect, at a minimum, both type certificate and supplemental type certificate design approval holders under FAR Parts 21 and 25, or equivalent.

We also assumed that any proposed new operational rules would affect all turbine-powered transport airplanes with a type certificate issued to large, medium, and small transport category airplanes operated under FAR Parts 91, 121, 125, or 129, or equivalent.

11.5 COST SUMMARIES

Figures 11-2 through 11-5 are cost summaries of all the inerting scenarios considered for the worldwide fleet, U.S. fleet, world passenger-only fleet, and U.S. passenger-only fleet.

Summary of Inerting Scenario Results World

Values in Millions	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports PSA/Membrane Systems	Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 11 - Ground Based Inerting HCWT only, All Transports	Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports	Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenic Systems & Small Transports, PSA/Membrane Systems	Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems & Small Transports, PSA/Membrane Systems	Scenario 16 - On-Board Liquid Nitrogen Inerting
Total $ Cost with Inflation	25,321	41,901	24,415	38,349	47,601	21,476	32,969	22,973	26,203	57,021	34,569	45,797	77,735
NPV in 2005 of Cost	11,592	18,509	11,240	17,035	20,775	9,896	14,936	10,374	11,885	24,605	15,440	20,405	31,527
Total Benefits	597	1,037	591	1,032	1,202	701	1,186	668	1,109	1,202	701	1,186	1,202
NPV in 2005 of Benefits	219	381	217	379	441	257	435	245	407	441	257	435	441

Figure 11-2. Cost Summary—Worldwide Fleet, All Transports

Summary of Inerting Scenario Results US-Operator

Values in Millions	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports PSA/Membrane Systems	Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 11 - Ground Based Inerting HCWT only, All Transports	Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports	Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenic Systems & Small Transports, PSA/Membrane Systems	Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems & Small Transports, PSA/Membrane Systems	Scenario 16 - On-Board Liquid Nitrogen Inerting
Total $ Cost with Inflation	10,082	15,367	9,744	14,203	17,047	8,606	12,680	10,429	11,588	20,924	13,586	17,414	27,692
NPV in 2005 of Cost	4,849	7,099	4,721	6,613	7,753	4,165	5,968	4,758	5,314	9,357	6,299	8,015	11,656
Total Benefits	233	434	231	432	497	274	492	258	459	497	274	492	497
NPV in 2005 of Benefits	86	159	85	159	183	101	181	95	169	183	101	181	183

Figure 11-3. Cost Summary—U.S. Fleet, All Transports

Summary of Inerting Scenario Results **World - PAX Only**

Values in Millions	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems	Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems	Scenario 11 - Ground Based Inerting HCWT only, All Transports	Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports	Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 16 - On-Board Liquid Nitrogen Inerting			
Total $ Cost with Inflation	21,474	34,897	20,722	32,007	39,168	18,015	27,575	21,286	24,085	47,094	28,866	38,157	65,236	-	-	-
NPV in 2005 of Cost	9,936	15,576	9,644	14,371	17,248	8,376	12,590	9,600	10,907	20,489	12,994	17,129	26,698	-	-	-
Total Benefits	597	1,037	591	1,032	1,202	701	1,186	668	1,109	1,202	701	1,186	1,202	-	-	-
NPV in 2005 of Benefits	219	381	217	379	441	257	435	245	407	441	257	435	441	-	-	-

Figure 11-4. Cost Summary—Worldwide Fleet, Passenger Planes Only

Summary of Inerting Scenario Results **US-Operator - PAX Only**

Values in Millions	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems & Small Transports, PSA/Membrane Systems	Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems	Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems	Scenario 11 - Ground Based Inerting HCWT only, All Transports	Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports	Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, & Small Transports, PSA/Membrane Systems	Scenario 16 - On-Board Liquid Nitrogen Inerting			
Total $ Cost with Inflation	7,588	10,898	7,352	10,149	11,675	6,349	9,194	9,321	10,207	14,550	9,868	12,474	19,817	-	-	-
NPV in 2005 of Cost	3,768	5,215	3,678	4,896	5,491	3,166	4,442	4,246	4,672	6,698	4,692	5,884	8,598	-	-	-
Total Benefits	233	434	231	432	497	274	492	258	459	497	274	492	497	-	-	-
NPV in 2005 of Benefits	86	159	85	159	183	101	181	96	169	183	101	181	183	-	-	-

Figure 11-5. Cost Summary—U.S. Fleet, Passenger Planes Only

12.0
Regulatory Impact